State of California
The Resources Agency
Department of Water Resources

FINAL REPORT
CHARACTERIZATION OF COLD WATER POOL AVAILABILITY IN THE THERMALITO AFTERBAY
SP-F3.1, TASK 4B

Oroville Facilities Relicensing
FERC Project No. 2100

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REPORT SUMMARY

The objective of this task was to evaluate whether sufficient cold water exists in the Thermalito Afterbay to support a year-round cold water fishery. The two potential types of cold water fisheries that Task 4B of SP-F3.1 was designed to assess were a put-and-grow salmonid trophy fishery, and a put-and-take salmonid sport fishery. Because residence times of stocked salmonids potentially would be different for put-and-grow or put-and-take fisheries, two thermal regimes were analyzed. Based on the reported thermal tolerances of coho salmon (*Oncorhynchus kisutch*), an index of appropriate water temperatures for a put-and-grow salmonid fishery was established as water temperatures less than or equal to 18°C (64.4°F) year-round. A water temperature range of 18.1°C (64.6°F) to 23.9°C (75.0°F) was utilized as an index of water temperatures capable of supporting a put-and-take salmonid fishery. The potential for both fisheries also was evaluated using the Environmental Protection Agency (EPA) reported 30-day mean dissolved oxygen requirement of 6.5 mg/l for the protection of adult and juvenile salmonids. During preliminary examination of the available water temperature data collected from the Thermalito Afterbay, it was determined that, during most of the year, sufficient cold water exists to sustain a salmonid fishery. Therefore, detailed analysis of cold water availability was conducted on data collected during June, July, and August 2002, the summer months, when water temperatures were the warmest during 2002.

Water temperature and dissolved oxygen profiles were collected over an 11-month period at 5 point locations and across 4 transects in the Thermalito Afterbay. Detailed analysis of the data was conducted for each of the three warmest months of the year (June, July, and August) because the water temperature profiles during those months were the warmest, most heterogeneous, and most dynamic of the water temperatures observed during the year. Additionally, surface water elevation fluctuations were greatest during the summer months in 2002. Water temperature profiles collected from the fall, winter, and spring months showed little variation between sampling locations, and showed that sufficient cold water was available during those months at the sampling locations, to support a cold water fishery. Therefore, the fall, winter, and spring months were omitted from further analysis.

Based on analysis of available data, in the summer months in 2002 when water temperatures in the Thermalito Afterbay were highest and water surface elevations fluctuated the most, water temperatures for both put-and-grow salmonid fishery management and put-and-take salmonid fishery management were suitable at the locations sampled. Therefore, continued operation of the Thermalito Complex facilities in a manner consistent with current operations would be expected to result in available cold water habitat to support salmonid management goals in the Thermalito Afterbay.

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1.0 INTRODUCTION

1.1 Background Information

Ongoing operation of the Oroville Facilities influences water temperatures and surface elevation fluctuations in the Thermalito Afterbay. Water temperature and surface elevation are important factors in influencing the availability of habitat for salmonids in the afterbay. As a component of study plan SP-F3.1, *Evaluation of Project Effects on Fish and their habitat within Lake Oroville, its upstream tributaries, the Thermalito Complex, and the Oroville Wildlife Area,* Task 4 describes fish species distribution, evaluates recruitment of juvenile bass, characterizes the cold water pool availability, and evaluates water level fluctuations in the Thermalito Afterbay. Task 4B, herein, evaluates potential project effects on habitat available to coldwater fish species.

1.1.1 Statutory/Regulatory Requirements

Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife, and botanical resources in the vicinity of the project (FERC 2001). The discussion is required to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact from on-going and future operations.

This task is additionally related to the FERC Relicensing of the Oroville Facilities because FERC has a long history of fish stocking in Lake Oroville and the Thermalito Forebay. In 1977, FERC approved the California Department of Water Resources' (DWR) Oroville Facilities Recreation plan entitled Bulletin No. 117-6 (Oroville Reservoir, Thermalito Forebay, and Thermalito Afterbay Water Resources Recreation Report), which provided plans for public utilization of project lands and waters including the Thermalito Afterbay for recreational purposes through the year 2017 (FERC 1994). However, there is no current stocking program in place for the Thermalito Afterbay.

As a subtask of SP-F 3.1, Task 4B fulfills a portion of the FERC application requirements and provides documentation to support future implementation of Bulletin No. 117-6 by providing an analysis of cold water availability for salmonids in the Thermalito Afterbay.

1.1.2 Study Area

The study area in which the results of Task 4B of SP-F3.1 apply is the Thermalito Afterbay.

1.1.2.1 Description

The Thermalito Afterbay is a large, shallow off-stream reservoir with a high surface-to-volume ratio and frequent water level fluctuations. Located approximately six miles southwest of the City of Oroville, the Thermalito Afterbay provides storage for water required by pump-back operations to Lake Oroville. In addition, the Thermalito Afterbay helps regulate the power production system, produces controlled flows in the Feather River downstream from the Oroville-Thermalito facilities, and provides recreation opportunities including limited sport fishing opportunities. It also serves as a warming basin for agricultural uses near the afterbay.

The Thermalito Afterbay holds a maximum of 57,040 acre-feet of water. The water surface elevation and water surface area at maximum operating storage are 136.5 feet and 4,300 acres, respectively. The shoreline covers approximately 26 miles at maximum operating storage (DWR 2001). The Thermalito Afterbay has a complex hydrologic regime due to the unpredictable timing of pump-back operations and the heterogeneous hydrogeomorphology of the reservoir (DWR 2001). Additionally, because the Thermalito Afterbay is shallow (approximate maximum depth of 20 feet), wind is a factor in determining the circulation patterns of water within the afterbay. An example of the complexity of the thermal regime results when wind causes some areas of the afterbay to mix thoroughly, maintaining a slow and uniform increase in water temperature, while other areas that are not influenced by wind tend to warm rapidly during the summer (DWR 2001). Also, during pump-back operations, water is released from the Thermalito Afterbay Outlet was well as pumped back into the power canal, thereby adding to the complexity to the circulation regime (DWR 2001). Pump-back operations usually occur at night, but the effect of the operations can reportedly last into the following day, as warmer water from the south afterbay is drawn into the north afterbay. After pump-back, cold water is released from the forebay through the tailrace canal into the afterbay, and mixing of cold and warm water drawn up from the south afterbay occurs.

Thermal stratification of the water in the Thermalito Afterbay has been reported to occur from April through November (DWR 2003). According to DWR water quality scientists, thermal stratification of the Thermalito Afterbay is most likely to occur in the summer months from June through early September (pers. com., M. Hendrick, DWR, 2003b).

Water surface elevations can fluctuate rapidly and frequently in the Thermalito Afterbay resulting in a high degree of variability in water levels from day-to-day, and from week-to-week, depending on project operations. Unlike Lake Oroville, in which water surface elevation fluctuates seasonally, the water surface elevation in the Thermalito Afterbay may fluctuate weekly because there is no set schedule for pump-back operations or release of water into the lower Feather River. Because pump-back operations occur as power generation is required, rather than on a set schedule, little is known about the residence time of water in the afterbay. Release of water for rice cultivation, regulation of river flows, and pump-back operations combined with wind mixing contribute to the variable nature of reservoir fluctuation as well as the variable residence times of water in the Thermalito Afterbay. During periods when operation of the Thermalito Afterbay causes weekly fluctuations, the reservoir level is lowered in the beginning of the week to accommodate power generation needs toward the end of the week. As power generation needs increase, the Thermalito Pumping-Generating Plant generates power and the reservoir fills. Therefore, by the end of the week, the reservoir water surface elevation is relatively high. Over the weekend, the reservoir is drawn down to provide storage capacity for the following week, allowing the cycle to repeat (pers. com., E. See, DWR, 2003b).

Figure 1.1-1 shows an infrared image of the surface water temperature in the Thermalito Afterbay. The image covers the northern part of the afterbay where the State Highway 162 bridge crosses the reservoir, representing approximately a one-half square mile area. Each color change on the image represents a change of approximately 0.5º Fahrenheit (F) with cool water temperatures represented in blue and warmer water temperatures represented in red. The image was acquired courtesy of AG-RECON at approximately 7:00 AM on June 22, 2002, and illustrates the effect of pump-back operation from the previous night. The warm water from the southern portion of the afterbay can clearly be distinguished from the cooler northern portion of the afterbay. The plume of orange and yellow extending from the bottom portion of the image toward the top portion illustrates the effect of warm water being pumped back from the southern portion of the afterbay into the cooler northern portion. The water temperature difference of the warm water (red) to the cool water (blue) in the northern portion of the afterbay is approximately 6º F (3.3º C) (Olson and AG-RECON 2002).

Because the Thermalito Afterbay exhibits a complex thermal regime, it provides warm water and cold water habitat. In addition to a popular largemouth bass (*Micropterus salmoides*) fishery, other warm water species including smallmouth bass (*Micropterus dolomieui*), spotted bass (*Micropterus punctulatus*), various species of sunfish (*Lepomis spp.*), bluegill (*Lepomis macrochirus rafinesque*), white crappie (*Pomoxis annularis rafinesque*), black crappie (*Pomoxis nigromaculatus*), catfish (*Ictalurus spp.* and *Ameiurus sp*), and common carp (*Cyprinus carpio*), have appeared in the afterbay (DWR 2001). Tule perch (*Hysterocarpus traski*) also has recently been confirmed in the afterbay (pers. com., E. See, DWR, 2003a). Although salmonids are not currently stocked, rainbow trout (*Oncorhynchus mykiss*) have been observed in the Thermalito Afterbay, and large trout are sometimes caught near the Thermalito Afterbay inlet. These fish likely pass through the Thermalito Pumping-Generating plant from the Thermalito Forebay (DWR 2001). It also is likely that most of the Lake Oroville sport fish also occur in the afterbay (DWR 2001). However, it has been reported that not all of the species found in the Thermalito Afterbay are found in Lake Oroville. Electrofishing efforts on November 21, 2002 near the Thermalito Afterbay Launch Ramp resulted in the capture of four brook trout (S*alvelinus fontinalis*), one rainbow trout and 33 Wakasagi (*Hypomesus nipponensis*). At the North End 1740 sampling point, electrofishing efforts produced one bluegill, one golden shiner (*Notemigonus crysoleucas*), five largemouth bass, one rainbow trout, and eleven Wakasagi. Sampling efforts at the Riprap sampling point resulted in ten bluegill, eight largemouth bass, one rainbow trout, and four Sacramento sucker (*Catostomus occidentalis*). The Rock Wall 730 sampling point yielded 27 bluegill, one hitch (*Lavinia exilicauda*), 17 largemouth bass, one rainbow trout, six sculpin (*Cottus sp.*), and five Wakasagi (pers. com., E. See, DWR, 2003c).

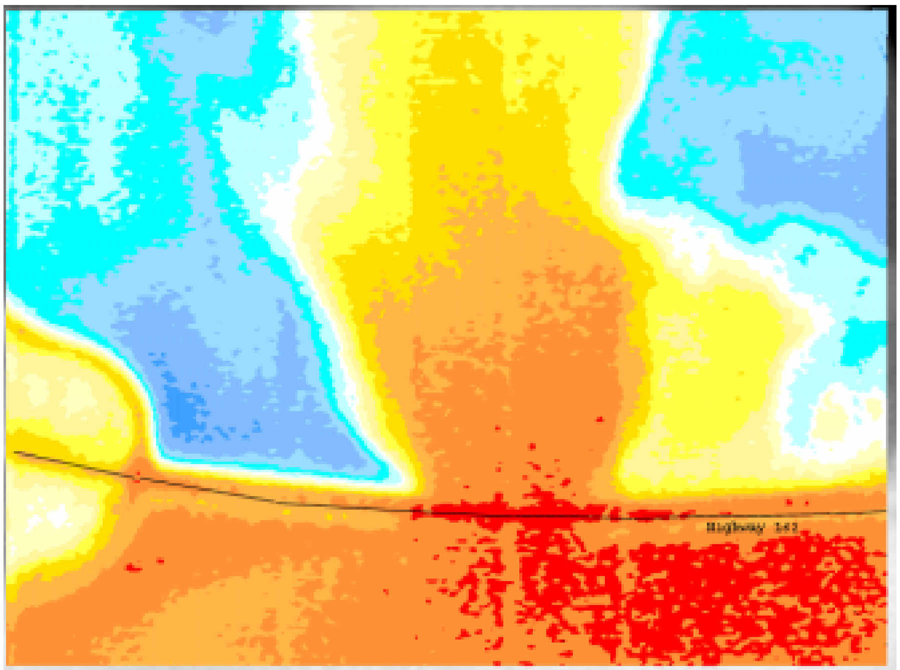

Figure 1.1-1. Infrared image of approximately one-half square mile of the Thermalito Afterbay near the Highway 162 Bridge.

Note: Different colors represent different surface water temperatures ranging from relatively cool (blue) to relatively warm (red). Each change in shade represents a half degree change in surface water temperature (°F). Image courtesy of AG-RECON, Davis, CA.

1.1.2.2 History

Summary of Salmonid Stocking in Lake Oroville

Since 1968 the California Department of Fish and Game (DFG) has stocked a variety of salmonids in Lake Oroville. From 1968 to 1978, rainbow trout, brown trout (*Salmo trutta*), coho salmon, and kokanee salmon (*Oncorhynchus nerka*) were the principally stocked salmonids in Lake Oroville (DWR 1999). Beginning in 1979, coho and kokanee salmon were no longer stocked in the lake and Chinook salmon (*Oncorhynchus tshawytscha*) were stocked instead (DWR 1999; DWR 2001). After 1988, rainbow trout were no longer stocked. From 1988 to 2000, brown trout and Chinook salmon were the principally stocked salmonids in Lake Oroville (DWR 1999). From 1990-2000, the Lake

Oroville cold water fishery was actively managed for Chinook salmon and brown trout (DWR 1999).

Recent disease concerns, including the prevalence of infectious hematopoietic necrosis virus (IHN), have prompted changes to the stocking practices for Lake Oroville. Due to their susceptibility to IHN, Chinook salmon and brown trout are not currently being stocked in the lake. Coho salmon were stocked as a replacement for Chinook salmon and brown trout in order to maintain an attractive cold water fishery in Lake Oroville, because coho salmon appear to be more resistant to IHN than other salmonid species (pers. com., E. See, DWR, 2003b). Oroville Hatchery coho salmon brood stock are selectively bred for the hatchery environment to be resistant to disease, and can withstand higher water temperatures than wild coho salmon (pers. com., E. See, DWR, 2003a). In addition, *Ceratomyxa shasta*, a myxozoan parasite that causes ceratomyxosis, and is lethal to most strains of rainbow trout, is prevalent in Lake Oroville (DWR 2001). The parasite has a complex life cycle, which includes a common freshwater polychaete worm, *Manayunkia speciosa*, as an alternate host (pers. com., E. See, DWR, 2003b). The worm host may thrive in the fine sediments found in impoundments, including Lake Oroville. It has been reported that the progression of ceratomyxosis is influenced by water temperature and that mortality increases in salmonids as water temperatures increase above 10°C (50°F), although it has been documented in some drainages to be infective at water temperatures below 6.1°C (43°F) (DWR 2002).

Summary of Salmonid Stocking in the Thermalito Forebay 1981-2001

A variety of salmonids have been stocked in the Thermalito Forebay since 1981. In the years between 1981 and 2001, except 1996 in which no salmonids were released, records show that DFG stocked the Thermalito Forebay with a total of 1,016,853 individual salmonids. Of the total number of salmonids stocked in the forebay, 898,355 (88.3 %) were rainbow trout, 91,140 (9.0 %) were brook trout, 16,000 (1.6 %) were Eagle Lake rainbow trout, and 7,400 (0.7 %) were brown trout. Another 933 (<0.1 %) were Pit River strain rainbow trout brood stock and 3,025 (0.3 %) were Chinook salmon (pers. com., E. See, DWR, 2003a).

DFG released rainbow trout into the Thermalito Forebay every year from 1981 through 2001 except for 1996, when no salmonids were released. The highest number of rainbow trout released in a single year was 127,435 in 1987. The lowest number of rainbow trout released in a single year was 18,380 in 1998. Brook trout releases began with 14,640 fish in 1993; the highest number introduced in a single year, and continued in 1994. Releases of brook trout were interrupted from 1995 through 1996 and resumed from 1997 through 2001. The lowest number of brook trout released was 5,760 in 1994 (pers. com., E. See, DWR, 2003a).

1.2 DESCRIPTION OF FACILITIES

The Oroville Facilities were developed as part of the State Water Project (SWP), a water storage and delivery system of reservoirs, aqueducts, power plants, and pumping plants. The main purpose of the SWP is to store and distribute water to supplement the needs of urban and agricultural water users in northern California, the San Francisco Bay area, the San Joaquin Valley, and southern California. The Oroville Facilities are also operated for flood management, power generation, to improve water quality in the Delta, provide recreation, and enhance fish and wildlife.

FERC Project No. 2100 encompasses 41,100 acres and includes Oroville Dam and Reservoir, three power plants (Hyatt Pumping-Generating Plant, Thermalito Diversion Dam Power Plant, and Thermalito Pumping-Generating Plant), Thermalito Diversion Dam, the Feather River Fish Hatchery and Fish Barrier Dam, Thermalito Power Canal, Oroville Wildlife Area (OWA), Thermalito Forebay and Forebay Dam, Thermalito Afterbay and Afterbay Dam, and transmission lines, as well as a number of recreational facilities. An overview of these facilities is provided on Figure 1.2-1. The Oroville Dam, along with two small saddle dams, impounds Lake Oroville, a 3.5-million-acre-feet (MAF) capacity storage reservoir with a surface area of 15,810 acres at its normal maximum operating level.

The hydroelectric facilities have a combined licensed generating capacity of approximately 762 megawatts (MW). The Hyatt Pumping-Generating Plant is the largest of the three power plants with a capacity of 645 MW. Water from the six-unit underground power plant (three conventional generating and three pumping-generating units) is discharged through two tunnels into the Feather River just downstream of Oroville Dam. The plant has a generating and pumping flow capacity of 16,950 cfs and 5,610 cfs, respectively. Other generation facilities include the 3-MW Thermalito Diversion Dam Power Plant and the 114-MW Thermalito Pumping-Generating Plant.

Thermalito Diversion Dam, four miles downstream of the Oroville Dam, creates a tail water pool for the Hyatt Pumping-Generating Plant and is used to divert water to the Thermalito Power Canal. The Thermalito Diversion Dam Power Plant is a 3-MW power plant located on the left abutment of the Diversion Dam. The power plant releases a maximum of 615 cubic feet per second (cfs) of water into the river.

The Power Canal is a 10,000-foot-long channel designed to convey generating flows of 16,900 cfs to the Thermalito Forebay and pump-back flows to the Hyatt Pumping-Generating Plant. The Thermalito Forebay is an off-stream regulating reservoir for the 114-MW Thermalito Pumping-Generating Plant. The Thermalito Pumping-Generating Plant is designed to operate in tandem with the Hyatt Pumping-Generating Plant and has generating and pump-back flow capacities of 17,400 cfs and 9,120 cfs, respectively. When in generating mode, the Thermalito Pumping-Generating Plant discharges into the Thermalito Afterbay, which is contained by a 42,000-foot-long earth-fill dam. The

Afterbay is used to release water into the Feather River downstream of the Oroville Facilities, helps regulate the power system, provides storage for pump-back operations, and provides recreational opportunities. Several local irrigation districts receive water from the Afterbay.

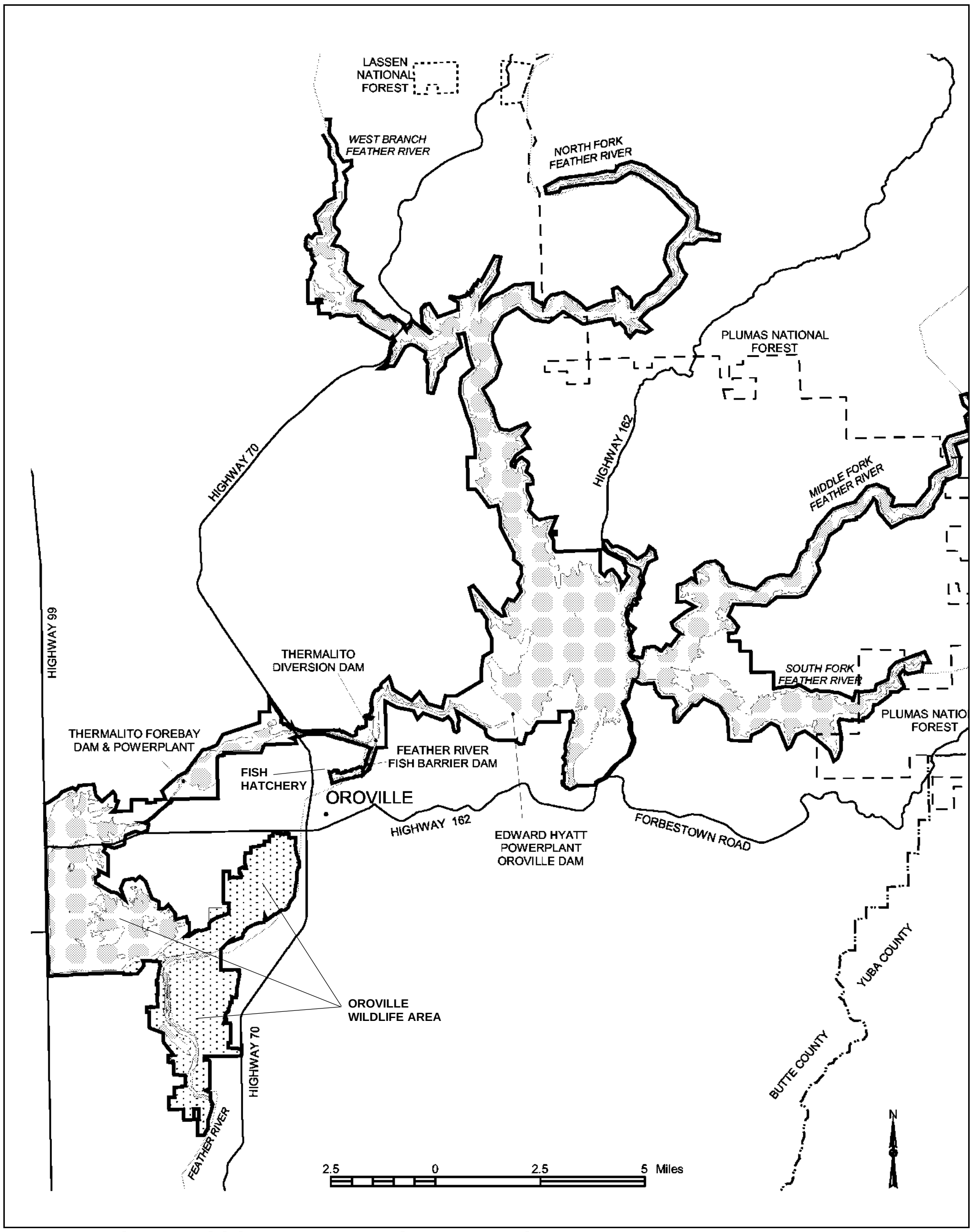

Figure 1.2-1. Oroville Facilities FERC Project Boundary.

The Feather River Fish Barrier Dam is downstream of the Thermalito Diversion Dam and immediately upstream of the Feather River Fish Hatchery. The flow over the dam maintains fish habitat in the low-flow channel of the Feather River between the dam and the Afterbay outlet, and provides attraction flow for the hatchery. The hatchery was intended to compensate for spawning grounds lost to returning salmon and steelhead trout from the construction of Oroville Dam. The hatchery can accommodate an average of 15,000 to 20,000 adult fish annually.

The Oroville Facilities support a wide variety of recreational opportunities. They include: boating (several types), fishing (several types), fully developed and primitive camping (including boat-in and floating sites), picnicking, swimming, horseback riding, hiking, off-road bicycle riding, wildlife watching, hunting, and visitor information sites with cultural and informational displays about the developed facilities and the natural environment. There are major recreation facilities at Loafer Creek, Bidwell Canyon, the Spillway, North and South Thermalito Forebay, and Lime Saddle. Lake Oroville has two full-service marinas, five car-top boat launch ramps, ten floating campsites, and seven dispersed floating toilets. There are also recreation facilities at the Visitor Center and the OWA.

The OWA comprises approximately 11,000-acres west of Oroville that is managed for wildlife habitat and recreational activities. It includes the Thermalito Afterbay and surrounding lands (approximately 6,000 acres) along with 5,000 acres adjoining the Feather River. The 5,000 acre area straddles 12 miles of the Feather River, which includes willow and cottonwood lined ponds, islands, and channels. Recreation areas include dispersed recreation (hunting, fishing, and bird watching), plus recreation at developed sites, including Monument Hill day use area, model airplane grounds, three boat launches on the Afterbay and two on the river, and two primitive camping areas. DFG's habitat enhancement program includes a wood duck nest-box program and dry land farming for nesting cover and improved wildlife forage. Limited gravel extraction also occurs in a number of locations.

1.3 CURRENT OPERATIONAL CONSTRAINTS

Operation of the Oroville Facilities varies seasonally, weekly and hourly, depending on hydrology and the objectives DWR is trying to meet. Typically, releases to the Feather River are managed to conserve water while meeting a variety of water delivery requirements, including flow, temperature, fisheries, recreation, diversion and water quality. Lake Oroville stores winter and spring runoff for release to the Feather River as necessary for project purposes. Meeting the water supply objectives of the SWP has always been the primary consideration for determining Oroville Facilities operation (within the regulatory constraints specified for flood control, in-stream fisheries, and downstream uses). Power production is scheduled within the boundaries specified by the water operations criteria noted above. Annual operations planning is conducted for multi-year carry over. The current methodology is to retain half of the Lake Oroville storage above a specific level for subsequent years. Currently, that level has been established at 1,000,000 acre-feet (af); however, this does not limit draw down of the reservoir below that level. If hydrology is drier than expected or requirements greater than expected, additional water would be released from Lake Oroville. The operations plan is updated regularly to reflect changes in hydrology and downstream operations. Typically, Lake Oroville is filled to its maximum annual level of up to 900 feet above mean sea level (msl) in June and then can be lowered as necessary to meet downstream requirements, to its minimum level in December or January. During drier years, the lake may be drawn down more and may not fill to the desired levels the following spring. Project operations are directly constrained by downstream operational constraints and flood management criteria as described below.

1.3.1 Downstream Operation

An August 1983 agreement between DWR and DFG titled, "*Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish & Wildlife*," sets criteria and objectives for flow and temperatures in the low flow channel and the reach of the Feather River between Thermalito Afterbay and Verona. This agreement: (1) establishes minimum flows between Thermalito Afterbay Outlet and Verona which vary by water year type; (2) requires flow changes under 2,500 cfs to be reduced by no more than 200 cfs during any 24-hour period, except for flood management, failures, etc.; (3) requires flow stability during the peak of the fall-run Chinook spawning season; and (4) sets an objective of suitable temperature conditions during the fall months for salmon and during the later spring/summer for shad and striped bass.

1.3.1.1 Instream Flow Requirements

The Oroville Facilities are operated to meet minimum flows in the lower Feather River as established by the 1983 agreement (see above). The agreement specifies that Oroville Facilities release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. This is the total volume of flows from the diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline.

Generally, the instream flow requirements below Thermalito Afterbay are 1,700 cfs from October through March, and 1,000 cfs from April through September. However, if runoff for the previous April through July period is less than 1,942,000 af (i.e., the 1911-1960 mean unimpaired runoff near Oroville), the minimum flow can be reduced to 1,200 cfs from October to February, and 1,000 cfs for March. A maximum flow of 2,500 cfs is maintained from October 15 through November 30 to prevent spawning in overbank areas that might become de-watered.

1.3.1.2 Water Temperature Requirements

The Diversion Pool provides the water supply for the Feather River Fish Hatchery. The hatchery objectives are 52°F for September, 51°F for October and November, 55°F for December through March, 51°F for April through May 15, 55°F for last half of May, 56°F for June 1-15, 60°F for June 16 through August 15, and 58°F for August 16-31. A temperature range of plus or minus 4°F is allowed for the objectives extending from April through November.

There are several temperature objectives for the Feather River downstream of the Afterbay Outlet. During the fall months, after September 15, the temperatures must be suitable for fall-run Chinook salmon. From May through August, they must be suitable for shad, striped bass, and other warmwater fish.

The National Marine Fisheries Service has also established an explicit criterion for steelhead and spring-run Chinook salmon. Memorialized in a biological opinion on the effects of the Central Valley Project and SWP on Central Valley spring-run Chinook salmon and steelhead as a reasonable and prudent measure, DWR is required to maintain daily average water temperature of $< 65^{o}$ F at Feather River Mile 61.6 (Robinson Riffle in the low flow channel) from June 1 through September 30. The requirement is not intended to preclude pump-back operations at the Oroville Facilities needed to assist the State of California with supplying energy during periods when the California ISO anticipates a Stage 2 or higher alert.

The hatchery and river water temperature objectives sometimes conflict with temperatures desired by agricultural diverters. Under existing agreements, DWR provides water for the Feather River Service Area (FRSA) contractors. The contractors claim a need for warmer water during spring and summer for rice germination and growth (i.e., 65°F from approximately April through mid May, and 59°F during the remainder of the growing season). There is no obligation for DWR to meet the rice water temperature goals. However, to the extent practical, DWR does use its operational flexibility to accommodate the FRSA contractor's temperature goals.

1.3.1.3 Water Diversions

Monthly irrigation diversions of up to 190,000 (July 2002) af are made from the Thermalito Complex during the May through August irrigation season. Total annual entitlement of the Butte and Sutter County agricultural users is approximately 1 MAF. After meeting these local demands, flows into the lower Feather River continue into the Sacramento River and into the Sacramento-San Joaquin Delta. In the northwestern portion of the Delta, water is pumped into the North Bay Aqueduct. In the south Delta, water is diverted into Clifton Court Forebay where the water is stored until it is pumped into the California Aqueduct.

1.3.1.4 Water Quality

Flows through the Delta are maintained to meet Bay-Delta water quality standards arising from DWR's water rights permits. These standards are designed to meet several water quality objectives such as salinity, Delta outflow, river flows, and export limits. The purpose of these objectives is to attain the highest water quality, which is reasonable, considering all demands being made on the Bay-Delta waters. In particular, they protect a wide range of fish and wildlife including Chinook salmon, Delta smelt, striped bass, and the habitat of estuarine-dependent species.

1.3.2 Flood Management

The Oroville Facilities are an integral component of the flood management system for the Sacramento Valley. During the wintertime, the Oroville Facilities are operated under flood control requirements specified by the U.S. Army Corps of Engineers (USACE). Under these requirements, Lake Oroville is operated to maintain up to 750,000 af of storage space to allow for the capture of significant inflows. Flood control releases are based on the release schedule in the flood control diagram or the emergency spillway release diagram prepared by the USACE, whichever requires the greater release. Decisions regarding such releases are made in consultation with the USACE.

The flood control requirements are designed for multiple use of reservoir space. During times when flood management space is not required to accomplish flood management objectives, the reservoir space can be used for storing water. From October through March, the maximum allowable storage limit (point at which specific flood release would have to be made) varies from about 2.8 to 3.2 MAF to ensure adequate space in Lake Oroville to handle flood flows. The actual encroachment demarcation is based on a wetness index, computed from accumulated basin precipitation. This allows higher levels in the reservoir when the prevailing hydrology is dry while maintaining adequate flood protection. When the wetness index is high in the basin (i.e., wetness in the watershed above Lake Oroville), the flood management space required is at its greatest amount to provide the necessary flood protection. From April through June, the maximum allowable storage limit is increased as the flooding potential decreases, which allows capture of the higher spring flows for use later in the year. During September, the maximum allowable storage decreases again to prepare for the next flood season. During flood events, actual storage may encroach into the flood reservation zone to prevent or minimize downstream flooding along the Feather River.

2.0 NEED FOR STUDY

As a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, Task 4B fulfills a portion of the FERC application requirements by characterizing cold water pool availability in the Thermalito Afterbay. In addition to fulfilling statutory requirements, the conclusions from this analysis may be used as the basis for developing or evaluating potential Resource Actions focused on providing appropriate water temperature regimes in the Thermalito Afterbay for management of a cold water fishery.

Performing this subtask also is necessary, in part, because operations of the Oroville Facilities affect surface elevation fluctuations in the Thermalito Afterbay which, in turn, directly impact and influence afterbay and in-river water temperature regimes (DWR 2001). Because water temperature is an important factor influencing the availability of habitat for various species of fish in the afterbay, Task 4B of SP-F3.1 evaluates potential project effects on habitat available to coldwater fish species in the Thermalito Afterbay.

3.0 STUDY OBJECTIVES

3.1 STUDY APPLICATION

The objective of Task 4B was to characterize cold water pool availability in the Thermalito Afterbay to support potential cold water fishery management goals. Additionally, data collected for this task could serve as a foundation for future evaluation and development of potential Resource Actions. One specific suggested Resource Action is the development and implementation of a salmonid stocking program in the Thermalito Afterbay. Therefore, an evaluation of cold water pool availability in the Thermalito Afterbay was necessary to provide the tools to determine whether the Resource Action would be feasible or beneficial (DWR 2003).

3.1.1 Department of Water Resources

The information from this study plan report would be used by DWR and the Environmental Work Group (EWG) to determine the feasibility of a year-round salmonid fishery in Thermalito Afterbay.

3.1.2 Other Studies

As a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*, Task 4 describes fish species distribution, evaluates recruitment of juvenile bass, characterizes the cold water pool availability, and evaluates water level fluctuations in the Thermalito Afterbay. Task 4A describes fish species composition and evaluates juvenile bass recruitment in the Thermalito Afterbay. Task 4C characterizes inundated littoral habitat and evaluates effects of surface elevation fluctuations on bass nest dewatering in the Thermalito Afterbay. Task 4B, herein, evaluates potential project effects on the amount of cold water habitat available to coldwater fish species. In order to characterize the cold water pool availability in the Thermalito Afterbay, water temperature and dissolved oxygen concentration profile data were obtained from sampling efforts for SP-W6.

Water temperature in the High Flow Channel (HFC) of the lower Feather River is typically warmer than water temperature in the Low Flow Channel (LFC) of the lower Feather River, partly because water temperature in the HFC is directly influenced by water releases from the Thermalito Afterbay. Because the Thermalito Afterbay is a large, shallow reservoir, water released from the Thermalito Afterbay Outlet is typically warmer than the water originating from the LFC of the main channel of the lower Feather River. Also, the contribution to the total flow in the Feather River from the Thermalito Afterbay Outlet is typically greater than flow contribution from the LFC of the lower Feather River (DWR 2001).

3.1.3 Engineering Exhibits

Although the ability of the Oroville Facilities to control water temperatures in the Lower Feather River is being examined in several engineering and operations study plans including SP-E1, SP-E6, and SP-E7, no modeling results were necessary to complete this study plan report because SP-F3.1 Task 4B required that the availability of cold water habitat in the Thermalito Afterbay be examined under current operating conditions.

3.1.4 Environmental Documentation

In addition to Section 4.51(f)(3) of 18 CFR, which requires reporting of certain types of information in the FERC application for license of major hydropower projects (FERC 2001), it may be necessary to satisfy the requirements of the National Environmental Policy Act (NEPA). Because FERC has the authority to grant an operating license to DWR for continued operation of the Oroville Facilities, NEPA mandates that the project FERC identify the potential impacts of the project on many types of resources, including fish, wildlife, and botanical resources. In addition, NEPA requires discussion of any anticipated continuing impact from on-going and future operations. To satisfy NEPA, DWR is preparing a Preliminary Draft Environmental Assessment (PDEA) to attach to the FERC license application, which shall include information provided by this study plan report.

3.1.5 Settlement Agreement

In addition to statutory and regulatory requirements, SP-F3.1 Task 4B could provide information to aid in the development of potential Resource Actions to be negotiated during the collaborative settlement process.

Also, information obtained from analysis of the availability of cold water for a cold water fishery could be used to determine operating procedures negotiated during the collaborative settlement process.

4.0 METHODOLOGY

4.1 STUDY DESIGN

4.1.1 Rationale For Selection of Water Temperature and Dissolved Oxygen Indices

Task 4B of SP-F 3.1 is specifically designed to evaluate cold water pool availability in the Thermalito Afterbay, and to analyze the suitability of available habitat for the goal of either a cold water sustained put-and-grow trophy fishery, or a cold water put-and-take sport fishery. In order to determine the availability of cold water habitat in the afterbay, SWRI analyzed the relationship between water temperatures suitable for coho salmon and the water temperatures observed in the Thermalito Afterbay during the warmest three months during which sampling occurred (June, July, and August 2002). Coho salmon were selected as the salmonid species for which thermal tolerance values would be analyzed because the species reportedly has the most narrow thermal tolerance range for growth as well as the lowest critical thermal maximum of all salmonid species likely to be considered for stocking in the afterbay (EPA 2002).

The water temperature and dissolved oxygen criteria chosen for the analysis of cold water habitat availability was based on the most protective EPA recommended criteria available for growth of adult and juvenile salmonids (EPA 2002). Additionally, the analysis considered the two potential management goals for a cold water fishery in the Thermalito Afterbay. The first potential management goal would be to meet index water temperatures for growth of juvenile and adult coho salmon for a sustained put-and-grow trophy fishery. The second goal would be to meet sublethal exposure water temperature indices for a put-and-take sport fishery. The index water temperatures chosen to meet either of the two potential management goals were based on the weekly maximum average water temperatures to which coho salmon could be exposed while meeting management goals. The EPA (2002) suggests that the maximum weekly average water temperature for growth of juvenile and adult coho salmon be 18°C (64.4°F). The maximum weekly average water temperature reported by the EPA for survival of juvenile and adult coho salmon is 24°C (75.2°F) (EPA 2002). Coho salmon were chosen to represent all salmonids with respect to water temperature tolerance because they reportedly have a more narrow water temperature tolerance range than other salmonid species considered for stocking in the afterbay (EPA 2002).

For this analysis, the water temperatures of 18°C and 24°C, indicated by the EPA to be the maximum weekly average water temperature to which coho salmon could be exposed and maintain growth and survival, respectively, were used as the index water temperatures for which analysis of suitable water temperatures for management goals were performed. The index water temperature range chosen to represent the ability of the afterbay to sustain a put-and-grow trophy fishery, therefore, included water temperatures at or below 18°C (64.4°F). For example, a sufficient amount of water with an average weekly water temperature at or below 18°C during the three warmest months of the sampling period indicated that the sampling locations within the Thermalito Afterbay could sustain a put-and-grow trophy fishery during that time period. The water temperature range chosen to indicate habitat suitability for a put-and-take fishery was from 18.1°C to 23.9°C (64.6°F to 75.0°F). Average weekly water temperatures including and higher than 24°C (75.2°F) were considered unsuitable for either fishery. The thermal tolerance index ranges defined in this report serve as technical evaluation guidelines for consideration in making resource management decisions.

The EPA reports that the minimum dissolved oxygen concentration to which salmonids can be exposed for 30 days and maintain growth is 6.5 mg/l (EPA 2002). The 7 day mean minimum dissolved oxygen concentration reported by the EPA to be tolerated by salmonids is 5.0 mg/l (EPA 2002). For acute exposures to low dissolved oxygen concentrations, the EPA reports that salmonids can tolerate a minimum dissolved oxygen concentration of 4.0 mg/l for one day while maintaining growth (EPA 2002). Because a put-and-grow trophy salmonid fishery would be required to persist for long periods of time in the afterbay, the thirty-day mean dissolved oxygen concentration criterion of 6.5 mg/l was chosen as an index of habitat suitability for the put-and-grow fishery management goal. Additionally, the thirty-day mean dissolved oxygen concentration criterion was chosen as an index of habitat suitability for the put-and-take salmonid fishery management goal, because it is the most protective of the EPA reported criteria for non-embryonic and non-larval salmonid life stages.

Because coho salmon are reported to have the most narrow thermal tolerance ranges of any salmonids that potentially could be considered for placement in the Thermalito Afterbay (EPA 2002), the water temperature ranges that maintain survival and allow growth of coho salmon would meet management goals for any salmonid species considered for placement in the afterbay. In addition, the EPA's recommended 30-day minimum dissolved oxygen concentration for growth of salmonids would meet management goals for all salmonid species considered for placement in the Thermalito Afterbay.

Limnological profiles obtained by DWR showing the concurrent distribution of water temperatures and dissolved oxygen concentrations by depth at multiple locations were utilized to provide the foundation for the analysis of usable cold water habitat for both of the possible management goals in the Thermalito Afterbay. A detailed description of the analytical procedures utilized in the analysis is provided below.

Currently neither DWR nor DFG are stocking the Thermalito Afterbay (pers. com., E. See, DWR, 2003a). Therefore, management of the Thermalito Afterbay is considered passive because any fish species currently in the afterbay have either passed through the facilities between the forebay and afterbay during project operations, have migrated into the afterbay from the lower Feather River, or have been placed in the afterbay by private parties (pers. com., E. See, DWR, 2003a).

4.1.2 Definition of Usable Cold Water Habitat

The approach for the analysis of usable cold water salmonid habitat in the Thermalito Afterbay utilized physiochemical characteristics measured over a sufficient time period in order to capture the variation in climatic and operational conditions. Usable cold water habitat was defined as the portion of the afterbay that met the physiochemical requirements for cold water fish habitat. Because this task was focused on assessing water temperature (i.e., availability of sufficient cold water to support salmonid stocking for either a sustained put-and-grow trophy fishery or a put-and-take sport fishery), and because dissolved oxygen concentrations are related to thermal stratification, both water temperature and dissolved oxygen criteria were used to identify usable cold water salmonid habitat for this analysis. Additionally, both water temperature and dissolved oxygen concentration were considered in the analysis of usable cold water because it is possible that water temperature may have been appropriate for salmonid utilization in a specific area, while dissolved oxygen concentrations may not have been appropriate for salmonid utilization in the same area. Considering only water temperature may have resulted in calculating usable habitat that, while appropriate for salmonids with respect to thermal tolerance, may not have been appropriate for salmonids when dissolved oxygen concentrations were additionally considered. Therefore, both water temperature and dissolved oxygen were used to define the usable cold water salmonid habitat in the Thermalito Afterbay.

For the purpose of this analysis, usable cold water habitat was defined as any portion of the Thermalito Afterbay in which both water temperature criteria and dissolved oxygen criteria were met concurrently. To determine the availability of cold water habitat for a put-and-grow trophy fishery, an index water temperature range representing potential water temperatures appropriate for coho salmon growth was chosen. Because the EPA reports that any water temperatures at or below 18°C (64.4°F) are suitable for growth of coho salmon (EPA 2002), those same water temperatures were considered suitable for a put-and-grow trophy fishery. To determine the availability of cold water habitat for a put-and-take salmonid fishery, the water temperature at which lethality occurs was chosen as an index water temperature representing the upper limit of potentially suitable water temperatures. The EPA reports that the maximum weekly average water temperature at which coho salmon can survive is 24°C (75.2°F) (EPA 2002). Because water temperatures at or below 18°C (64.4°F) are considered by the EPA to be suitable for coho salmon growth, and water temperatures at or above 24°C (75.2°F) are considered lethal to coho salmon by the EPA, a range of water temperatures between 18.1°C and 23.9°C (64.6°F to 75.0°F) was chosen as the index water temperature range by which water temperature suitability for a put-and-take salmonid fishery was determined.

4.1.3 Analytical Approach

Because coho salmon reportedly have the lowest thermal tolerance of any salmonid species stocked in Lake Oroville, they were chosen as the species for which water temperature tolerances would be analyzed (EPA 2002). The overall analytical approach was to compare available water temperature and dissolved oxygen concentration data in the Thermalito Afterbay with water temperature index values for put-and-grow, and put-and-take coho salmon management considerations.

4.2 DATA COLLECTION

Water temperature and dissolved oxygen concentration data were collected by DWR at eight locations consisting of four transects and four point locations within the Thermalito Afterbay between June 6, 2002 and August 29, 2002.

4.2.1 Sampling Locations

Water temperatures (°C) and dissolved oxygen concentrations (mg/l) were collected from four transects (A-D) in the Thermalito Afterbay. In inclement weather dissolved oxygen concentration data were not collected because DWR staff safety was a concern. Therefore, the minimum amount of time possible was spent on the open water. Additionally, equipment malfunction precluded collection of dissolved oxygen concentration data during some sampling efforts. Figure 4.2-1 shows the locations of each of the four transects within the afterbay. Each transect contained between 9 and 10 sampling profiles, except on one occasion, when equipment failure allowed for only 3 profiles to be obtained. Because surface water elevation fluctuations dewatered portions of some transects on some sampling dates, which resulted in the slight fluctuation in number of profiles, uniform distribution between sampling profiles within each transect was difficult to maintain (pers. com., M. Hendrick, DWR, 2003a). In addition, surface water elevation fluctuations caused differences in depth profiles between sampling dates. Data were collected over an 11-month period and were collected either monthly or biweekly, depending on the season in which samples were collected. During the summer months when the likelihood of thermal stratification and increased water temperatures was highest, data were collected biweekly. Detailed discussion of the sampling period is discussed below. Whenever possible, data collected on subsequent sampling dates at a given location were collected during the same time of day as previous sampling efforts at the same location to minimize the confounding effects of diel changes in water quality on the analysis. Global Positioning Satellite (GPS) locations of each of the transect termini and point locations are presented in Table 4.2-1.

Transect A is located in the North Afterbay, north of the Highway 162 bridge, while Transects B, C, and D are located in the South Afterbay. Transect B is located immediately south of the Highway 162 bridge, while Transect C is located in the southwest portion of the South Afterbay. Transect D is located opposite the Thermalito Afterbay Outlet.

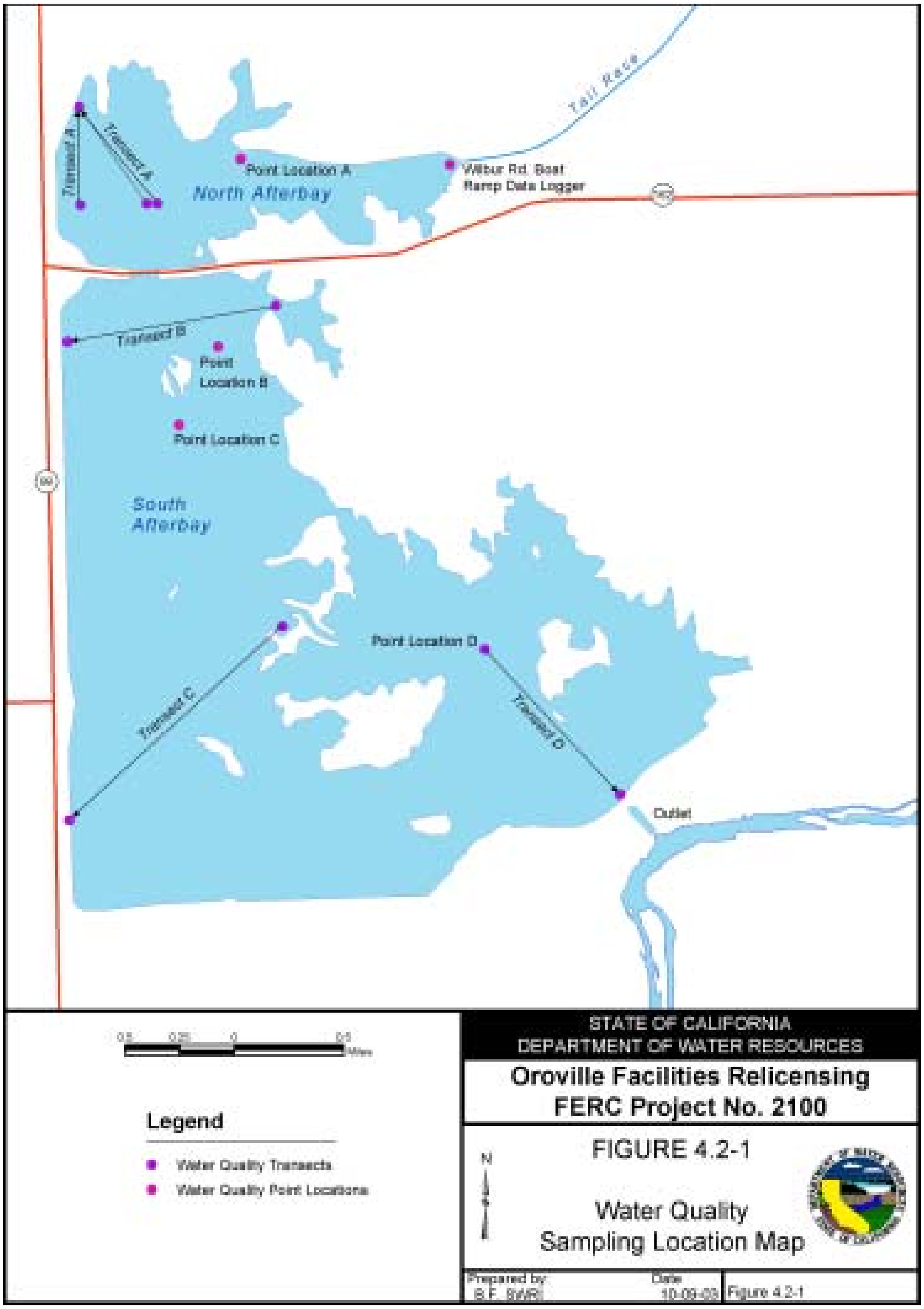

Figure 4.2-1. Locations of Transects, Point Location Profiles, and the Fixed Water Quality Station.

Table 4.2-1. Global Positioning Satellite (GPS) coordinates of Point Locations and Transect termini.

Station Name	Latitude	Longitude
Point Location A	N 39 30' 4.3"	W 121 40' 17.9"
Point Location B	N 39 29' 19.4"	W 121 40' 25.8"
Point Location C	N 39 29' .8"	W 121 40' 38.1"
Point Location D	N 39 28' 5.7"	W 121 39' 5.1"
Transect A		
Start	N 39 29' 53.9"	W 121 41' 7.4"
End	N 39 30' 17.3"	W 121 41' 7.4"
Start	N 39 29' 53.9"	W 121 40' 46.8"
End	N 39 30' 17.3"	W 121 41' 7.4"
Start	N 39 29' 53.9"	W 121 40' 43.8"
End	N 39 30' 17.3"	W 121 41' 7.4"
Transect B		
Start	N 39 29' 28.9"	W 121 40' 7.5"
End	N 39 29' 21.1"	W 121 41' 12.2"
Transect C		
Start	N 39 28' 12.1"	W 121 40' 7.2"
End	N 39 27' 26.4"	W 121 41' 13.7"
Transect D		
Start	N 39 28' 5.7"	W 121 39' 5.1"
End	N 39 27' 30.5"	W 121 38' 24.0"

In addition to the four transects, physiochemical profiles were collected at four point locations. Point profile location samples were collected in shallow coves. Figure 4.2-1 shows the location within the afterbay of each of the four point profile locations. Water temperature, dissolved oxygen concentration, electrical conductivity, and pH were measured at each of the point profile locations. Data were collected over the same time period as the transect data. Point Location A is located in the North Afterbay, north of the Highway 162 bridge. Point Location B and C are located between Transects B and C in the South Afterbay. Point Location D is an endpoint of Transect D in the South Afterbay, near the Thermalito Afterbay Outlet.

Finally, there is a fixed water quality datalogger located in the North Afterbay that collected data one meter below the water surface on an hourly basis. The data logger is located at the terminus of the tailrace channel to the Thermalito Afterbay, near the Wilbur Road boat ramp (pers. com., J. Kindopp, DWR, 2003). Figure 4.2-1 shows the location of the fixed water quality station.

Transect locations were chosen by DWR staff to be representative of conditions within the Thermalito Afterbay to determine how water warmed as it moved through the Afterbay.

4.2.2 Instrumentation

Water temperature and dissolved oxygen concentration were generally measured using a Yellow Springs Instrument (YSI) probe that was re-calibrated at each profile location, within each transect, and at each point profile location. On some occasions DWR water quality scientists used a multi-parameter probe capable of determining water temperature, dissolved oxygen, pH, electrical conductivity and turbidity. Calibration of the multi-parameter probe was performed when deemed necessary by experienced operators (pers. com., M. Hendrick, DWR, 2003b).

4.2.3 Period of record

Water temperature and dissolved oxygen concentration profiles used in this analysis to characterize the availability of cold water habitat in the Thermalito Afterbay were collected over a period of 11 months. Data were not collected continuously (i.e., each day of the month) during this time period, but rather monthly during most of the sampling period, and biweekly during the summer months. The time period (June 6 to August 29, 2002), utilized for in-depth analysis, represents the period in which the volume of usable cold water habitat for salmonids in the Thermalito Afterbay is most likely to be the smallest due to a combination of warm air temperatures leading to increased water temperatures, and potential oxygen depletion associated with thermal stratification.

Data were collected during the summer months from the transects and point locations on June 6 (Table 5-1), July 2 and 31 (Table 5-2), and August 1 and 29 (Table 5-3).

4.2.4 Calculation of Volume of Usable Cold Water Habitat and Data Limitations

Because operating procedures for the Thermalito Afterbay are based on a variety of factors including power supply needs, it is difficult to predict surface water fluctuations and water volume in the afterbay. Therefore, the study design proposed in SP-F3.1 could not accurately account for surface water elevation and afterbay volume fluctuations during the sampling period. Although data collection efforts were as uniform as possible between sampling events, fluctuations in surface water elevation and afterbay volume that occurred during the sampling period precluded calculation of the volume of usable cold water habitat using the available data.

In addition, due to uncontrollable circumstances such as equipment malfunction or inclement weather during the sampling period, some gaps in the continuity of the data exist. Transects A through C had no data for July, although data for two sets of point locations were collected in July. On July 7 point locations A through D were sampled, and on July 31 point locations B through D were sampled. In August, Transect B was omitted. As described above, each of the four transects had fixed beginning and end points. GPS coordinates of each beginning and end point for each transect are shown in Table 4.2-1 and the geographic locations are shown in Figure 4.2-1. Because the water surface levels in the afterbay fluctuated substantially over the course of the sampling period, some portions of the transects were dewatered during some sampling events, and actual wetted transect lengths changed between sampling efforts. Evidence of these changes is exhibited as differences in transect lengths and profile depths presented in Section 5.0, Results, in Table 5-1 through Table 5-3.

Changing afterbay conditions during the sampling period that caused differences in sampling procedures (i.e., variable transect lengths due to water surface elevation fluctuations) caused some degree of variability in the collected data. In addition, a lack of transect data for three of the four transects during the month of July, and lack of data for one transect in August, added to the variability between sampling events. The variability in data collected during separate sampling events precluded calculating the volume of usable cold water habitat.

5.0 RESULTS

Analysis of cold water habitat availability in the Thermalito Afterbay was performed on data collected during the summer of 2002. Data were collected on June 6 (Table 5-1), July 2, July 31 (Table 5-2), August 1 and August 29 (Table 5-3). Analysis of the data revealed relatively little exceedance of index water temperatures. Water temperatures less than or equal to 18°C (64.4°F) are reported to be suitable for growth for coho salmon and were selected as the water temperature index range suitable for a put-and-grow cold water fishery. Water temperatures between 18.1°C (64.6°F) and 23.9°C (75.0°F) are considered sub-lethal to coho salmon and were selected as indices to determine suitability for a put-and-take cold water fishery. Water temperatures equal to or greater than 24°C (75.2°F) were considered beyond the suitable range for either a put-and-take or a put-and-grow cold water fishery.

5.1 WATER TEMPERATURE

Only one sample, collected on June 6, 2002 at the surface at Point Location D, which was also one endpoint of Transect D (1), fell outside the suitable water temperature index range for the put-and-take cold water fishery. The recorded water temperature at that location was 24.7°C (76.5°F). Water temperatures below the surface at Point Location D remained between 18.1°C and 23.9°C, the range selected as suitable for a put-and-take salmonid fishery. Table 5-1 shows the water temperatures recorded during the June 6 sampling effort. Water temperatures obtained in June along Transects A, B and C fell preponderantly within the range reported by EPA (2002) as suitable for coho salmon growth (less than or equal to 18°C). Most water temperatures recorded in June along Transect D fell within the sub-lethal index range reported by EPA (2002) (18.1°C to 23.9°C). However, water temperatures in the deepest portions of the transect remained at or below 18°C, within the range reportedly suitable for coho salmon growth.

Water temperature data from the July 2 sampling date are mostly consistently distributed between the water temperatures considered in this analysis to be an index of suitability for a put-and-take cold water fishery, and for a put-and-grow cold water fishery. Water temperatures collected from the July 31 sampling event from Transect D fell entirely within the index range considered suitable for a put-and-take cold water fishery, while the data collected from Transects A and C the following day (August 1) indicate water temperatures were within the index range considered suitable for a put-and-grow cold water fishery, with no single sample water temperature above 17°C (62.6°F). Tables 5-2 and 5-3 show the water temperature data collected in July and August.

Table 5-1. Water temperature (ºC) readings from the ten sampling profiles of Thermalito Afterbay Transects A, B, C and D, and of four isolated point location profiles, taken on June 6, 2002.

Transect A — Water Temperature (ºC) per Profile

Depth (m)	1	2	3	4	5	6	7	8	9	10
0	13.6	12.7	12.8	13.5	13.6	14.5	14.7	14.7	16.4	14.9
0.5	(13.5)	(12.7)	(12.8)	(13.2)	(13.1)	(14.1)	(13.9)	(14.0)	(15.8)	(14.8)
1	13.3	12.6	12.8	12.8	12.5	13.7	13.0	13.2	15.1	14.7
1.5	13.0	12.6	12.8	12.8	12.7	13.0	13.0	13.2	14.6	14.4
2		12.6	12.7	12.7	12.6	12.8	12.9	13.1	13.9	14.4
2.5		12.6	12.7	12.7	(12.6)	(12.8)		13.1	(13.6)	(14.4)
3			12.7		12.6	12.7			13.3	14.3
3.5			12.7		12.6				13.2	(14.2)
4										14.0
4.5										(13.8)
5										13.6
5.5										(13.4)
6										13.2
6.5										13.1
7										
7.5										
8										

Transect B — Water Temperature (ºC) per Profile

Depth (m)	1	2	3	4	5	6	7	8	9	10
0	18.0	17.9	17.0	17.8	15.7	13.7	13.7	14.1	14.1	14.1
0.5	(17.6)	(17.5)	(16.2)	(16.2)	(15.0)	(13.7)	(13.7)	(14.1)	(14.1)	(14.0)
1	17.1	17.1	15.4	14.5	14.3	13.6	13.6	14.0	14.0	13.9
1.5	15.9	15.8	14.5	13.7	13.6	13.5	13.6	13.9	13.7	13.7
2					13.6	13.5	13.6	13.8	13.5	13.5
2.5							13.5	13.7	13.4	13.5
3							13.5	13.7	13.4	13.4
3.5							13.5	13.7	13.3	13.4
4									13.3	13.3
4.5									13.3	13.3
5										
5.5										
6										
6.5										
7										
7.5										
8										

Transect C — Water Temperature (ºC) per Profile

Depth (m)	1	2	3	4	5	6	7	8	9	10
0	22.3	17.9	20.1	18.8	18.3	18.0	18.2	17.9	17.5	17.2
0.5	(20.0)	(17.9)	(17.8)	(17.3)	(16.8)	(17.0)	(18.1)	(17.7)	(17.4)	(17.0)
1	17.7	17.9	15.5	15.8	15.3	16.0	18.0	17.5	17.3	16.8
1.5	17.6	17.4	15.2	15.5	15.2	(15.7)	(17.5)	(17.3)	(17.1)	(16.7)
2				15.2	15.1	15.4	17.0	17.0	16.8	16.5
2.5				15.1	(15.1)	(15.4)	(16.4)	(16.8)	(16.6)	(16.4)
3				15.1	15.0	15.4	15.8	16.6	16.4	16.3
3.5								(16.3)	(16.2)	(16.2)
4								16.0	16.0	16.1
4.5								(17.0)	(15.9)	(16.0)
5								18.0	15.8	15.9
5.5									15.6	
6										
6.5										
7										
7.5										
8										

Transect D — Water Temperature (ºC) per Profile

Depth (m)	1	2	3	4	5	6	7	8	9	10
0	24.7	23.8	23.8	23.7	22.9	23.5	22.3	21.0	20.2	22.1
0.5	(22.0)	(21.4)	(21.2)	(21.2)	(20.6)	(20.9)	(20.5)	(20.0)	(19.7)	(21.4)
1	19.2	18.9	18.6	18.7	18.2	18.2	18.7	18.9	19.1	20.6
1.5	18.4	(18.5)	18.3	18.1	(18.1)	(18.1)	(18.4)	(18.6)	(18.7)	(19.6)
2	18.2	18.1	18.1	17.9	18.0	17.9	18.0	18.3	18.3	18.6
2.5	18.1	(18.1)			(17.9)	(17.8)	(17.9)	(18.1)	18.1	(18.5)
3		18.0			17.8	17.7	17.8	17.9		18.3
3.5					17.6					
4										
4.5										
5										
5.5										
6										
6.5										
7										
7.5										
8										

Isolated Profiles — Water Temperature (ºC) per Profile

Depth (m)	A	B	C	D
0	14.7	20.0	16.9	24.7
0.5	(14.4)	(17.8)	(16.3)	(22.0)
1	14.1	15.5	15.6	19.2
1.5	14.0		15.5	18.2
2	14.0		15.4	18.2
2.5	14.0			18.1
3				
3.5				
4				
4.5				
5				
5.5				
6				
6.5				
7				
7.5				
8				

Red	≥ 24 ºC
Yellow	18.1 ºC - 23.9 ºC
Green	≤ 18 ºC

Note: Water temperatures in parentheses indicate temperatures interpolated as an average value of the surrounding values.

Table 5-2. Water temperature (ºC) readings from three sampling profiles of Thermalito Afterbay Transect D, during July 31, 2002, and of four isolated point location profiles, during July 2, 2002, and three isolated point location profiles, during July 31, 2002.

Transect D

Depth (m)	Water Temperature (ºC) per Profile									
	1	2	3	4	5	6	7	8	9	10
0	23.2	22.5	22.5							
0.5	(22.2)	(21.6)	(21.5)							
1	21.1	20.6	20.4							
1.5	19.5	19.3	18.9							
2		19.0	18.4							
2.5										
3										
3.5										
4										
4.5										
5										
5.5										
6										
6.5										
7										
7.5										
8										

Isolated Profiles

Depth (m)	Water Temperature (ºC) per Profile			
	A	B	C	D
0		17.4	16.8	23.2
0.5		(16.8)	(16.6)	(22.2)
1		16.2	16.3	21.2
1.5				19.5
2				
2.5				
3				
3.5				
4				
4.5				
5				
5.5				
6				
6.5				
7				
7.5				
8				

Isolated Profiles

Depth (m)	Water Temperature (ºC) per Profile			
	A	B	C	D
0	19.7	17.5	18.7	22.0
0.5	(18.6)	(16.8)	(18.3)	(21.0)
1	17.4	16.1	17.8	19.9
1.5	17.0	16.1	17.2	19.1
2			16.9	18.9
2.5				
3				
3.5				
4				
4.5				
5				
5.5				
6				
6.5				
7				
7.5				
8				

≥ 24 ºC
18.1 ºC - 23.9 ºC
≤ 18 ºC

Note: Water temperatures in parentheses indicate temperatures interpolated as an average value of the surrounding values.

Table 5-3. Water temperature (ºC) readings from the ten sampling profiles of Thermalito Afterbay Transects A and C, and of one isolated point location profile, during the August 1, 2002, sampling event and from the ten sampling profiles of Thermalito Afterbay Transect D and four isolated point location profiles, during the August 29, 2002 sampling event.

Transect A

Depth (m)	Water Temperature (°C) per Profile									
	1	2	3	4	5	6	7	8	9	10
0	14.2	14.6	13.9	15.1	14.9	14.9	15.7	16.6	17.2	16.8
0.5	(14.0)	(14.1)	(13.8)	(14.8)	(14.8)	(14.9)	(15.3)	(15.9)	(16.2)	(16.7)
1	13.7	13.5	13.6	14.4	14.7	14.8	14.8	15.1	15.2	16.6
1.5	13.4	13.5	13.5	13.8	14.0	(14.3)	(14.4)	(14.6)	(15.0)	(15.9)
2	13.3	13.4	13.4	13.5	13.9	13.8	13.9	14.1	14.7	15.2
2.5		(13.4)	(13.4)	13.5		(13.8)	13.8	14.0	(14.5)	(15.0)
3		13.4	13.4			13.7			14.3	14.8
3.5			(13.4)			(13.7)			(14.2)	(14.7)
4			13.4			13.7			14.1	14.6
4.5										(14.6)
5										14.5
5.5										(14.4)
6										14.2
6.5										(14.2)
7										14.2
7.5										
8										

Transect C

Depth (m)	Water Temperature (°C) per Profile									
	1	2	3	4	5	6	7	8	9	10
0	17.0	16.3	16.0	16.1	16.1	15.7	15.3	15.4	15.3	15.8
0.5	(16.4)	(16.3)	(16.0)	(16.1)	(15.8)	(15.5)	(15.1)	(15.2)	(15.2)	(15.5)
1	15.8	16.2	15.9	16.0	15.5	15.3	14.9	14.9	15.0	15.2
1.5		(16.0)	(15.6)	(15.5)	(15.1)	(15.0)	(14.8)	(14.7)	(14.9)	(15.0)
2		15.8	15.3	15.0	14.6	14.6	14.6	14.5	14.7	14.7
2.5		(15.7)	(15.2)	(14.8)	(14.4)	(14.4)	(14.3)	(14.3)	(14.6)	14.4
3		15.5	15.1	14.6	14.2	14.1	14.0	14.0	14.4	
3.5					14.2	(14.1)	(13.9)	(14.0)	(14.4)	
4						14.1	13.8	13.9	14.3	
4.5						14.0		13.8	(14.3)	
5									14.3	
5.5									14.2	
6										
6.5										
7										
7.5										
8										

Isolated Profile

Depth (m)	Water Temperature (°C) per Profile			
	A	B	C	D
0	19.8			
0.5	(17.4)			
1	15.0			
1.5	14.8			
2	14.7			
2.5				
3				
3.5				
4				
4.5				
5				
5.5				
6				
6.5				
7				
7.5				
8				

Transect D

Depth (m)	Water Temperature (°C) per Profile									
	1	2	3	4	5	6	7	8	9	10
0	21.1	20.9	21.2	20.9	20.7	20.9	19.9	19.4	19.3	19.3
0.5	(21.0)	(20.9)	(21.0)	(20.2)	(19.9)	(20.7)	(19.7)	(19.0)	(19.3)	(19.3)
1	20.9	20.8	20.7	19.4	19.0	20.4	19.4	18.6	19.3	19.2
1.5	20.7	(20.6)	(20.2)	18.9	(18.7)	(19.3)	(18.8)	(18.5)	(19.0)	(19.1)
2	20.6	20.4	19.6	18.7	18.3	18.2	18.1	18.4	18.7	19.0
2.5		(20.0)	(19.4)		(18.3)	18.2	(18.1)	(18.4)	(18.6)	(18.6)
3		19.5	19.1		18.2		18.1	18.4	18.4	18.1
3.5									18.2	18.0
4										
4.5										
5										
5.5										
6										
6.5										
7										
7.5										
8										

Isolated Profiles

Depth (m)	Water Temperature (°C) per Profile			
	A	B	C	D
0	20.6	17.8	18.4	21.1
0.5	(20.4)	(17.7)	(18.3)	(21.0)
1	20.2	17.5	18.1	20.9
1.5	19.3	17.2	17.9	20.7
2		17.0	17.7	20.6
2.5			17.5	
3				
3.5				
4				
4.5				
5				
5.5				
6				
6.5				
7				
7.5				
8				

≥ 24 ºC
18.1 ºC - 23.9 ºC
≤ 18 ºC

Note: Water temperatures in parentheses indicate temperatures interpolated as an average value of the surrounding values.

Analysis of the data collected from the August 29 sampling event from Transect D shows that only one of the water temperatures fell within the index range considered suitable for a put-and-grow cold water fishery (less than or equal to 18°C), while the remaining water temperatures fell within the index range considered suitable for a put-and-take cold water fishery (18.1°C to 23.9°C). Data collected from all four isolated point profiles on August 29 showed nine readings from point locations A, C, and D between 18.1°C and 23.9°C. Seven recorded water temperatures from point locations B and C indicated water temperatures at or below 18°C, which is within the EPA reported growth range for coho salmon and the suitable index range for a put-and-grow cold water fishery.

The permanent datalogger location in the North Afterbay near Wilbur Road boat ramp opposite the western terminus of the tail race channel recorded water temperature data hourly at a depth of one meter. All water temperature readings from this profile were less than or equal to 15.5°C (59.9°F) for all sampling dates during the period of June 6 through August 29, 2002.

Data collected during the sampling period indicate that July was the warmest month in 2002 with regard to water temperatures in the Thermalito Afterbay. However, only one transect was sampled during the month. Data were collected from Transect D on July 31, 2002 with three water temperature-depth profiles along the transect being sampled. The water temperatures ranged from 23.2°C (73.8°F) at the surface of the first profile to 18.4°C (65.1°F) at a depth of two meters in the third profile of the transect (Table 5-1). The majority of the water temperature measurements collected in July 2002 were point location profiles. Four sets of point location data were collected on July 2, 2002 and three sets of point location profile data were collected on July 31 2002. The data collected on July 31 from Point Location D showed the warmest water temperatures for the three-month period analyzed. However, Point Location D also was an endpoint of Transect D.

In August, one of the data points located along Transect D indicated a water temperature of 18°C (64.4°F), while the remaining data points along Transect D indicated water temperatures between 18.1°C (64.6°F) and 23.9°C (75.0°F). In June, 13 data points collected from Transect D indicated water temperatures at or below 18°C (64.4°F), while 51 data points indicated water temperatures between 18.1°C (64.6°F) and 23.9°C (75.0°F). One data point indicated a water temperature above 24°C (75.2°F). All water temperatures at or below 18°C collected from Transect D in June were collected at or below a depth of two meters. The surface water temperatures from Point Location D, which is also a terminus of Transect D (1), on June 6, exhibited a surface water temperature of 24.7°C (76.5°F), outside the index range considered suitable for juvenile and adult coho salmon. The remaining surface water temperatures for Transect D (profiles 2 through 10) fell within the index range considered suitable for a put-and-take cold water fishery (18.1°C to 23.9°C). The other two transect water temperature profiles (Transects A and C) for August 2002 fell within the index range reported by EPA (2002) to be suitable for growth (less than or equal to 18°C), and within the index range considered suitable for a put-and-grow cold water fishery.

Unexpected water temperature data were obtained from the point location sampling sites during August, 2002. Surface water temperatures collected from Point Location A on August 1, 2002 were the second highest for any sampling date for that location, while water temperatures from depths of one half meter through two meters were among the coolest for that date.

5.2 DISSOLVED OXYGEN

Throughout the sampling period dissolved oxygen concentrations at all depths and at all locations exceeded 6.5 mg/l, the thirty-day mean concentration determined by the EPA for the protection of cold water aquatic species. The lowest dissolved oxygen concentration obtained during any sampling period was 6.8 mg/l.

6.0 ANALYSES

6.1 EXISTING CONDITIONS/ENVIRONMENTAL SETTING

Task 4B is a subtask of SP-F3.1, *Evaluation of Project Effects on Fish and Their Habitat within Lake Oroville, its Upstream Tributaries, the Thermalito Complex, and the Oroville Wildlife Area*. Task 4B fulfills a portion of the FERC application requirements by evaluation of potential project effects on Thermalito Afterbay habitat suitability for cold water fisheries. Additionally, data collected for this task could serve as a foundation for future evaluation and development of potential Resource Actions. One specific suggested Resource Action is the development and implementation of a salmonid stocking program in the Thermalito Afterbay.

6.2 PROJECT-RELATED EFFECTS

Salmonids reportedly thrive in dynamic environments if the water is fairly cool and well oxygenated (Moyle 2002). Because water temperature controls the internal body temperature of fish, it can regulate physical activity and physiological processes. However, fish may behaviorally thermoregulate by changing their relative location within the water column if favorable conditions exist (Larsen and Beschta et al. *in* Fact Sheet No. 27, 1987).

Because few water temperature data points exist from the Thermalito Afterbay from July 2002, and the water temperature data indicate that July was the warmest month with regard to water temperatures, the data should be closely scrutinized. Specifically, the location of Transect D, near the Thermalito Afterbay outlet, should be considered when attempting to draw conclusions about water temperatures in July 2002. Because Transect D displayed the warmest water temperatures during the June and August sampling events, when other transect data were available, it is possible that, in July, other transect locations would have yielded cooler water temperatures than Transect D. Additionally, the data collected on July 31 from Point Location D showed the warmest water temperatures for the three-month period analyzed. It was expected, however, that water temperatures would be warmest at Pont Location D because it is located opposite the Thermalito Afterbay Outlet, a relatively large distance from the cold water influx in the North Afterbay (see Figure 4.2-1). Because the water quality data collected in July 2002 only exists for one transect and most point locations (Table 5-2), care should be taken when attempting to draw conclusions about water temperatures and cold water habitat availability throughout the Thermalito Afterbay in July 2002.

Overall, based on analysis of the data collected from four point locations and four transect locations in the Thermalito Afterbay, it appears that, throughout the warmest months of the sampling period, sufficient cold water exists to support a cold water fishery in some portions of the afterbay. Although the volume of cold water in the afterbay could not be accurately determined, all transect and point locations displayed water temperatures within the reported sub-lethal or growth ranges for coho salmon for the three warmest summer months. These data indicate that there would be a cold water refuge for salmonids in the northern part of the Thermalito Afterbay.

Additionally, analysis of the data collected from all transects and point location profiles from June, July and August (Tables 5-1 through 5-4) illustrate the highly variable conditions in the Thermalito Afterbay. The data further indicate that thermal stratification during the summer may not exist, perhaps as a result of mixing and short residence time in the afterbay due to project operations as well as the shallow depth of the Afterbay.

7.0 REFERENCES

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